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CENTRAL INTELLIGENCE AGENCY

INFORMATION FROM

FOREIGN DOCUMENTS OR RADIO BROADCASTS

REPORT

CD NO.

50X1-HUM

COUNTRY	USSR	DATE OF INFORMATION	1950
SUBJECT	Scientific - Electricity, locomotives		
HOW PUBLISHED	Monthly periodical	DATE DIST.	27 Nov 1950
WHERE PUBLISHED	Moscow	NO. OF PAGES	4
DATE PUBLISHED	Feb 1950		
LANGUAGE	Russian	SUPPLEMENT TO REPORT NO.	

THIS IS UNEVALUATED INFORMATION

SOURCE Elektrichestvo, No 2, 1950, pp 78-82.

USSR DIESEL-ELECTRIC LOCOMOTIVES

Ye. Ya. Gakkel'
Cand Tech Sci, Doc Leningrad

/Figures referred to are appended./

During the past 25 years many types of diesel locomotives with electric drive have been produced in the USSR and abroad, as a result of the initial development work in our country.

In most cases the electric drive consists of an independently excited dc generator and a series traction motor. The traction motors usually have individual drive and streetcar system of suspension. The chief difference in principle between the various electric circuits lies in the system and methods used to regulate the voltage at the generator terminals. We give below a brief survey of some of the electric circuits of USSR diesel locomotives which are interesting as examples showing the lines along which the electric drive has developed.

The circuit of the G^{e}-1 (Shch-EL-1) locomotive was influenced by the fact that the manufacturing facilities available made it necessary to split the power between two generators. However, this fact was utilized by designers Ya. M. Gakkel' and V. F. Mitkevich to improve the regulation. The generators run in parallel and in series, while the traction motors are permanently connected in parallel. Provision is made for one generator to feed five motors. The voltage at the generator terminals is controlled by a rheostat in the excitation circuit. One generator is used as a motor to start the internal-combustion engine, during which process it is fed from a storage battery.

The circuit of the E-EL-2 locomotive, in contrast to that of the Shch-EL-1, is a quadratic generator-motor system. This gives 26 voltage regulation steps, with a small controller. However, due to generator switching, acceleration is not as smooth as that of the Shch-EL-1. No provision is made for using a generator

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as a starting motor. The exciter group is driven by a separate auxiliary internal-combustion engine. As can be seen, this locomotive has more electrical equipment than the Shch-EL-1, without any improvement in regulation and with poorer utilization of the possibilities of electric drive. The five traction motors are permanently connected in parallel; the streetcar system of suspension is used.

The first automatic regulation system for a heavy-duty locomotive is that of the G^e-19 (Figure 1), which was the first locomotive to have group-driven traction motors. In contrast to previous schemes, the voltage at the generator terminals is altered by varying the speed of the diesel. Power is automatically kept constant at a given diesel speed when the generator load current varies by means of the exciter, which operates as a voltage-dropping device since one of its windings is fed from part of the generator load current. The designer, Prof Ya. M. Gakkel', took out a patent in 1928 under the title "Automatic Regulation of DC Generators for the Purpose of Maintaining Constant Power," including three varients of the scheme. (Patent No 6396 published 19 September 1928 in accordance with Application No 9012 of 11 June 1926). This was no deterrent to foreign firms who suggested similar schemes more than 10 years later and claimed world priority in this field.

The plans for the G^e-19 diesel locomotive drawn up by the Bureau for Constructing Ya. M. Gakkel' Diesel Locomotives were approved by the People's Commissariat for Railroad Communications under the designation E-EL-4. Unfortunately, this locomotive was not built because the "Krasnyy Putilovets" plant which took the work in hand ceased building locomotives in 1928.

The circuit (Figure 2) and general arrangement of the electric drive of the DEGAT "Dizel'," "Elektrosila," Gakkel', Alekseyev, Teplovoz 1,900-hp diesel locomotive are of interest. The project placed first at the International Competition for Diesel Locomotive Projects held in Moscow in 1928. It was designed by Ya. M. Gakkel', A. Ye. Alekseyev, and engineers of the "Elektrosila," and "Russkiy Dizel'" plants. The traction motors are of the vertical, double support-frame type located at the two ends of the locomotive frame with a shaft drive to three of the six coupled axles from each double motor. The voltage at the generator terminals is altered by a rheostat in the excitation circuit of the exciter. The traction motors are usually connected in parallel. In the freight model only, it is possible to connect pairs of motors in series so as to avoid overheating the generator when there is a heavy load of rolling stock on the drawbars.

The diesel locomotives built by the Kolomenskiy plant in 1929 - 1937 -- the serially produced 1,050-hp main line E-EL train locomotive, the experimental 600-hp O-EL switching engine, and also the first segmented, two-unit diesel locomotive, the 2 x 1,050-hp type VM -- have the same circuit in principle. The chief differences are in the load circuit of the generator, as the number of traction motors varies according to type. One of the two O-EL type locomotives has a group drive from one support-frame motor; all the others have individual drive and streetcar motor suspension. In the control system of the locomotives of the Kolomenskiy plant, there is a tendency toward unified control of the entire power equipment of the locomotive. This is done through two controllers -- a drive controller, whose purpose is to alter the voltage at the generator terminals by introducing a rheostat into its excitation circuit, and an excitation controller, whose purpose is to maintain constant voltage at the exciter terminals. The excitation controller shaft is mechanically connected with the drive of the fuel regulator. When the shaft turns, the supply of fuel to the engine cylinders is increased at the same time as the resistance in the excitation circuit of the exciter is increased. As a result, the voltage at the exciter terminals is kept constant at all diesel speeds.

Since 1947, the Khar'kov Diesel Locomotive-Building Plant, in conjunction with the Khar'kov Electromechanical Plant and the "Dinamo" Plant, has been carrying out serial production of 1,000-hp TE-1 diesel locomotives. These locomotives were the first to vary the generator voltage over a wide range by altering the diesel speed. Control is from the engineer's cab through an electropneumatic system connected to the fuel equipment. The controller has eight positions, corresponding to diesel speeds of 270-740 rpm and, consequently, to different generator voltages. Automatic regulation of the generator for the purpose of maintaining constant power at constant speed while the load current varies, is accomplished by differential-compound excitation of the exciter by the load current of the generator. To improve regulation of the locomotive, the circuit (Figure 3) provides for series and series-parallel connection of the traction motors and also for weakening their excitation. The corresponding connections take place automatically when the locomotive attains the specified motor speeds. Great attention has been paid to automatic protection -- there is a maximum current relay, an interlocking relay, a relay for shutting off engine fuel in the event of insufficient lubrication, etc. The TE-1 locomotive has many of the features of the Shch-EL-1. These include the use of a generator as a starting motor for the diesel, individual drive for the traction motors, and flat tubular coolers.

This confirms the correctness of the trend of USSR technology, from the beginning, of diesel locomotive construction. It also spotlights the fact that the multiplicity of diesel-electric locomotives abroad, particularly in the USA, is due in many cases, not to the discovery of better systems, but to the personal enrichment of the industrialists who hold the patents.

The orderly development of all branches of USSR technology is reflected in many improvements to the diesel locomotive. The TE-1 diesel is supercharged, the energy in the exhaust gases being used for this purpose. This increases the engine's power by more than 25%. Moreover, the diesel is very flexible, which characteristic, in conjunction with the use of a regulator effective over the full range, enables generator voltage to be regulated by altering diesel speed. The diesel-generator group has a common shaft which increases the over-all efficiency of the unit. The traction motors have forced cooling which increases their overload capacity. Extensive use of modern relays and contactors ensures protection for the power circuit elements and automatic switching in its electrical circuit. Automatic generator regulation is of great importance in regard to the most advantageous utilization of all the power elements, i.e., diesel engine, generator, and traction motors. As a result of all the improvements, the efficiency of the diesel locomotive has already reached the value 29-30%, and fuel consumption has been reduced to 40-45 kg per 10,000 ton-km gross.

At the beginning of 1949 the Khar'kov plant produced the first new TE-2 segmented (two-unit) diesel locomotive, which is a combination of two 1,000-hp units controlled from one position by means of a multiple unit system. The power equipment of each unit is similar to that of the TE-1. There is a difference in the traction motor circuit; there are only four motors instead of six. Since there is a corresponding reduction in the number of axles, the construction of the frame is lighter in order to maintain the axle loading within the permitted limits. As a result of all the changes, the weight of the locomotive is very low--84 kg/hp.

Thus, it is apparent that the new type of traction started 25 years ago is being successfully developed and all the premises on which its design was based are fully justified.

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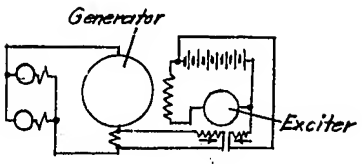

Figure 1

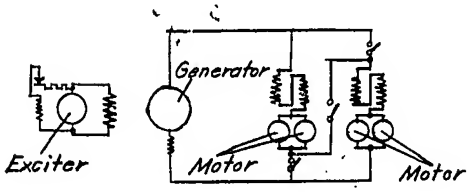

Figure 2

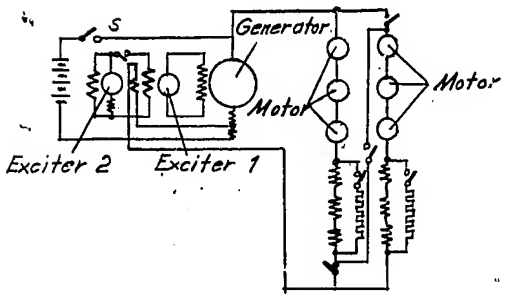

Figure 3

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